

# **CMOS-Compatible Piezoelectric Microphone**

***Eun Sok Kim***

**Department of Electrical Engineering  
University of Hawaii at Manoa  
Honolulu, HI 96822**

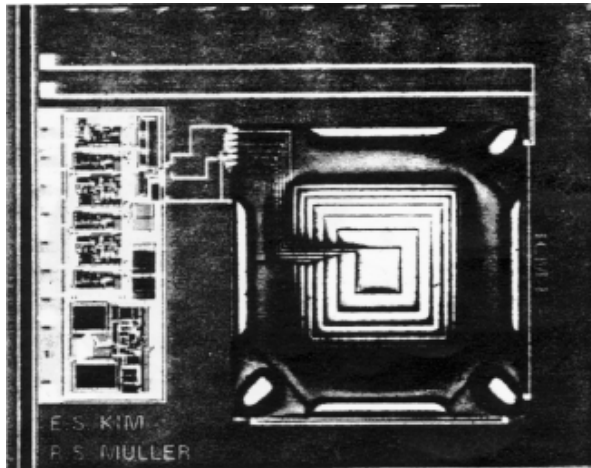
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**Department of Electrical Engineering-Electrophysics  
University of Southern California  
Los Angeles, CA**

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## Piezoelectric Microphone vs. Condenser Microphone

	Piezoelectric Microphone	Condenser Microphone
Sensitivity	relatively low	good
Polarization Voltage	not needed	needed
Dynamic Range	wide	relatively narrow
Fabrication	simple	relatively complicated
CMOS Compatibility	demonstrated 10 yrs ago	demonstrated 2 yrs ago

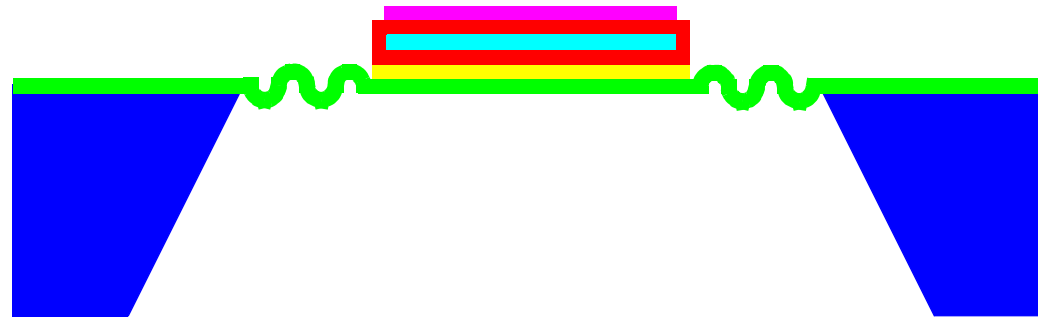
## Residual Stress on Piezoelectric Microphone



residual stress in thin diaphragm  
↓  
dominates diaphragm deflection  
↓  
limited sensitivity

**Integrated Microphone with 1 mv/Pa Unamplified Sensitivity  
(R. P. Ried, et al., J. of MEMS, Vol. 2, Sept. 1993, pp. 111-120)**

## Microphone on Corrugated Diaphragm



**silicon  
substrate**



**1.0  $\mu\text{m}$  thick  
silicon nitride**



**0.2  $\mu\text{m}$  thick  
doped poly-Si**



**0.2  $\mu\text{m}$  thick LTO**



**0.4  $\mu\text{m}$  thick  
zinc oxide (ZnO)**



**0.4  $\mu\text{m}$  thick  
aluminum**



# Theoretical Microphone-Sensitivity Calculation

- **Average Stress in the ZnO for Acoustic Pressure of 1  $\mu$ bar**

$$\ddagger \sigma = 1.0 \times 10^4 \text{ Pa}$$

- **Polarization in the ZnO**

$$\ddagger P = d_{31} \times \sigma = 5.0 \times 10^{-6} \text{ C/m}^2$$

$$\text{with } d_{31} = 5.0 \times 10^{-12} \text{ C/N for ZnO}$$

- **Electrical Field in the ZnO for Open Circuit**

$$\ddagger E = P / \epsilon_r \epsilon_0 = 5.0 \times 10^{-6} / (10.3 \times 8.85 \times 10^{-12}) = 549 \text{ V/m}$$

- **Open-Circuit Output Voltage**

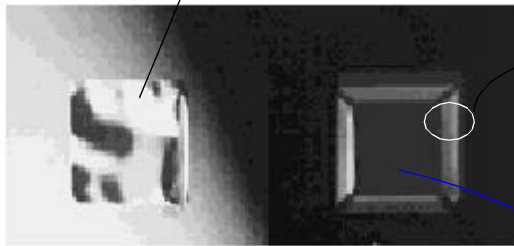
$$\ddagger V_s = Et = 549 \times 4.0 \times 10^{-7} = 0.220 \text{ mV}$$

with  $t$  being the ZnO thickness

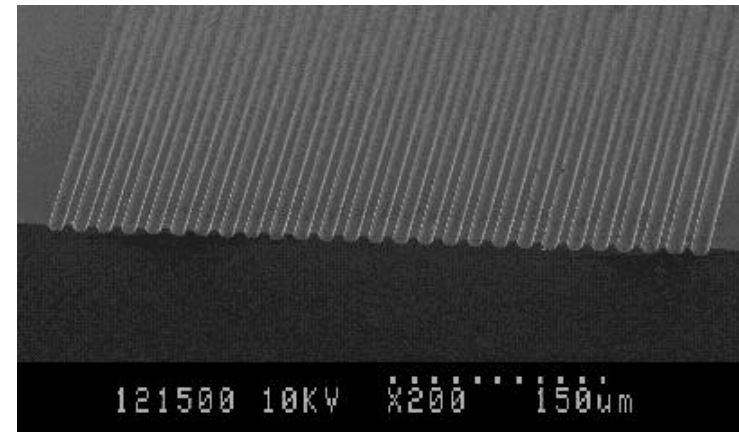
**Open Circuit Sensitivity: 220  $\mu$ V/ $\mu$ bar !**

# Stress Release by Corrugation on Diaphragm

wrinkled diaphragm  
due to compressive stress



Corrugation Cross Section



partly-corrugated diaphragm

## Summary

- **Piezoelectric Microphone:**  
advantageous over condenser microphone except sensitivity
- **Major Sensitivity-Limiting Factor in Piezoelectric Microphone:**  
residual stress in the diaphragm
- **Modeled and demonstrated**  
stress releasing effect of corrugations
- **Fabricated and tested**  
piezoelectric microphones with/without corrugation
- **Expected Sensitivity of Piezoelectric Microphone:**  
 $220 \mu\text{V}/\mu\text{bar}$  or  $2.2 \text{ mV}/\text{Pa}$